

(19) World Intellectual Property Organization  
International Bureau(43) International Publication Date  
1 August 2002 (01.08.2002)

PCT

(10) International Publication Number  
WO 02/059456 A1

(51) International Patent Classification: E21B 43/10

(21) International Application Number: PCT/GB03/00356

(22) International Filing Date: 28 January 2002 (28.01.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
0103021.3 26 January 2001 (26.01.2001) GB(71) Applicant (for all designated States except US): E2  
TECH LIMITED [GB/GB]; Shell International B.V., PO  
Box 384, NL-2501 CJ The Hague (NL).

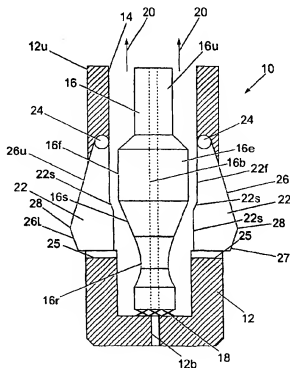
(72) Inventors; and

(75) Inventors/Applicants (for US only): OOSTERLING, Peter [NL/NL]; Noordeindseweg 128, NL-2651 CX Berkel

en Roderijs (NL), MACKENZIE, Alan [GB/GB]; 2 Con-  
tlaw Place, Milltimber, Aberdeen AB13 0DS (GB).(74) Agent: MURGITROYD & COMPANY; 165-169 Scot-  
land Street, Glasgow G5 8PL (GB).(81) Designated States (national): AE, AG, AL, AM, AT, AU,  
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,  
CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM,  
HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK,  
LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX,  
MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL,  
TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.(84) Designated States (regional): ARIPO patent (GH, GM,  
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),  
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),  
European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR,  
GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent

[Continued on next page]

(54) Title: EXPANDER DEVICE



(57) Abstract: Apparatus (9) for radially expanding an expandable member, the apparatus including a plurality of radially moveable fingers (22). The radially moveable fingers (22) can move between two positions; in a first position, the moveable fingers (22) are radially extended to form a cone to facilitate radial expansion of the expandable member; in the second position, one or more of the radially moveable fingers (22) can move radially inward so that restrictions in the path of the apparatus can be by-passed.

WO 02/059456 A1

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## — with international search report

## EXPANDER DEVICE

1  
2  
3 The present invention relates to apparatus that is  
4 particularly suited for radially expanding expandable  
5 members, such as liners, casings, tubulars and the  
6 like.  
7  
8 It is known to use an expander device to expand at  
9 least a portion of an expandable member. Expandable  
10 members are typically of a ductile material so that  
11 they can undergo plastic and/or elastic deformation  
12 using an expander device. Expandable members can  
13 include liner, casing, drill pipe and other tubulars.  
14 Use of the term "expandable member" herein will be  
15 understood as being a reference to any one of these  
16 and other variants that are capable of being radially  
17 expanded by application of a radial expansion force,  
18 generally applied by the expander device, such as a  
19 cone. An expandable member is typically used within  
20 a borehole either to complete an uncased portion of a  
21 borehole, or to repair a damaged portion of a pre-  
22 installed liner or casing, for example.

1  
2 The initial outer diameter (OD) of the expandable  
3 member is typically less than the inner diameter (ID)  
4 of the borehole, or a pre-installed portion of liner,  
5 so that the expandable member can be run into the  
6 borehole. An expander device can then be forced  
7 through the expandable member, and at least a portion  
8 of the expander device has an OD that is typically  
9 the same as, or slightly less than, the ID of the  
10 uncased borehole or previously installed liner.  
11 Thus, as the expander device passes through the  
12 expandable member, the OD of the expandable member is  
13 increased so that an outer surface of the expandable  
14 member is pressed against an inner wall of the  
15 uncased borehole, or the inner surface of the pre-  
16 installed liner.  
17  
18 Prior art expander devices are typically of a hard  
19 material, such as tungsten carbide, and are typically  
20 of a solid construction, for example a solid cone.  
21 As the expander device (e.g. a cone) is pushed or  
22 pulled through the expandable member, it can become  
23 stuck due to, for example, immovable portions of the  
24 inner wall of the uncased borehole that protrude  
25 inwards into the path of the expander device.  
26  
27 In such a case, the travel of the expander device may  
28 be restricted by the inward protrusion, and as a  
29 result, the expansion process cannot be completed, as  
30 the device becomes stuck at the protrusion.  
31

1 When the expander device becomes stuck, it is  
2 necessary to retrieve the device from the borehole,  
3 typically by a fishing operation. Fishing operations  
4 generally require the expander device to be detached  
5 from a drill string or the like that is used to push  
6 or pull the expander device through the expandable  
7 member. Once the expander device has been detached,  
8 the drill string can be removed from the borehole,  
9 thus leaving the expander device therein. Clearly,  
10 the expander device must also be removed from the  
11 borehole to allow the recovery of hydrocarbons  
12 therefrom.

13

14 A typical fishing operation may involve the use of a  
15 tungsten carbide wash over-mill that is attached to  
16 an end of a drill string. The wash over-mill is  
17 rotated with the drill string, and the mill is  
18 inserted into the borehole to engage the obstruction  
19 and cut it away at its outer edges. However, as the  
20 wash over-mill cutters are generally made from the  
21 same material as the expander cone, they wear quickly  
22 and so this type of fishing operation is problematic.

23

24 Although other types of conventional fishing  
25 operations may be used, they all have a number of  
26 disadvantages. If the expander device does become  
27 stuck, the drill string used to push or pull it must  
28 be fully removed from the borehole, once the expander  
29 device has been detached. Boreholes can be many  
30 kilometres in length, and removal of the string in  
31 such cases is a very time consuming operation.

1     Thereafter, the stuck expander device must be  
2     retrieved using a conventional fishing operation.  
3     Having retrieved the expander device, a new device is  
4     attached to the end of the drill string, which is  
5     then lowered into the borehole to allow the expansion  
6     of the expandable member to continue. It may also be  
7     necessary to remove the obstruction (e.g. by using a  
8     wash over-mill) before the expansion process can  
9     continue.

10

11    This process results in a long rig downtime which can  
12    be very expensive due to the high costs involved,  
13    particularly on offshore rigs.

14

15    According to a first aspect of the present invention,  
16    there is provided apparatus for expanding an  
17    expandable member, the apparatus comprising a first  
18    member, one or more radially movable portions, a  
19    second member, and force isolating means acting  
20    between the first and second members.

21

22    The first member typically comprises a housing. The  
23    housing may comprise a cylindrical member with a  
24    blind bore. The isolating means is typically coupled  
25    between a first end of the second member and the  
26    blind end of the bore. Alternatively, the isolating  
27    means is coupled between a lower face of the first  
28    member, and a face provided on the second member.

29

30    The second member typically comprises a shaft having  
31    a cone that bears against the radially movable

1 portions (typically fingers pivotally mounted on the  
2 first member). The shaft and cone typically move  
3 axially with respect to the first member in and out  
4 of engagement with the radially movable portions  
5 (e.g. the fingers).

6  
7 A second end of the second member is typically  
8 provided with attachment means for attaching the  
9 apparatus to a drill string or the like. The  
10 attachment means may comprise any conventional means  
11 such as screw threads (e.g. box and/or pin  
12 connections) or the like.

13  
14 The fingers are typically coupled to the first member  
15 so that they can move in a radial and/or axial  
16 direction. Thus, the fingers can expand or contract  
17 to adjust an outer diameter of the apparatus.  
18 Typically, the fingers are held in a radially  
19 expanded position by the cone on the second member  
20 moving axially with respect to the first member to a  
21 first position in which the spring is contracted. In  
22 that first position, an outer surface of the cone  
23 abuts against an inner surface of the fingers and  
24 prevents them from moving radially inward. However,  
25 solid protrusions in the path of the fingers cause  
26 the force in the axial direction applied to the  
27 second member to extend the spring where the axial  
28 force exceeds the force of the spring. As the spring  
29 extends, the second member moves axially under the  
30 axial pulling force, and the cone moves to a second  
31 position that allows the fingers to move radially

1 inward to bypass the restriction. As the restriction  
2 is passed, the axial pulling force drops below the  
3 biasing force of the spring as the force that is  
4 retarding the apparatus is overcome, the spring  
5 contracts and the second member moves into engagement  
6 with the fingers causing them to move radially  
7 outward to the radially expanded position.  
8 Additionally, the engagement of the fingers with the  
9 restriction can cause them to move inwards against  
10 the cone thereby moving it to the second position in  
11 which the spring is extended. In this way, if the  
12 apparatus encounters a restriction or the like, the  
13 fingers can retract until the apparatus has passed  
14 the restriction and then expand once passed.

15  
16 By selecting the strength of the spring, the  
17 apparatus can be programmed to move the fingers at a  
18 given axial force that is typically greater than the  
19 force used to push or pull the apparatus. The given  
20 axial force can take into account the retarding force  
21 applied to the second member due to the obstruction.

22  
23 The fingers are typically pivotally coupled to the  
24 first member using a pivot, such as a pivot pin,  
25 hinge or the like. Optionally, a biasing means may  
26 be provided to bias the fingers radially outward.  
27 The biasing means may comprise a torsion spring that  
28 is positioned at the pivot.

29  
30 An outer face of the fingers typically defines a  
31 cone. The outer faces of the fingers are typically



1 angled so that the cone formed thereby faces in the  
2 direction of travel of the apparatus. Thus, as the  
3 apparatus is moved in the direction of travel, the  
4 outer faces engage an inner wall of the expandable  
5 member or the like to expand the expandable member.

6  
7 Optionally, the outer faces may include a second  
8 sloping face that is angled so that the apparatus can  
9 expand the inner diameter of the tubular when moved  
10 in the opposite direction to the normal direction of  
11 travel. In this embodiment, there is provided a  
12 double-sided cone that can be used in either  
13 direction of travel to expand the expandable member.

14  
15 The cone of the second member typically comprises an  
16 enlarged diameter portion. The enlarged diameter  
17 portion is preferably located so that it is aligned  
18 on the axis of the apparatus with the fingers. The  
19 enlarged diameter portion is provided with an outer  
20 profile that allows the fingers to move inwards when  
21 the second member is moved axially within the first  
22 member. Thus, the fingers can contract to allow the  
23 apparatus to pass restrictions or obstructions. An  
24 inner face of the fingers is typically provided with  
25 a corresponding profile.

26  
27 The outer profile typically comprises a flat portion  
28 extending in the axial direction, and a sloping  
29 portion. The profile on the inner face of the  
30 fingers typically comprises a flat portion extending  
31 in the axial direction, and a sloping portion. The

1 sloping portion is preferably set at a shallow angle.  
2 In use, the flat portion and the sloping portion  
3 provided on the enlarged diameter portion engage  
4 respectively with the flat portion and the sloping  
5 portion provided on the inner face of the fingers.  
6 Thus, the second member supports the fingers in the  
7 radially expanded position during the expansion  
8 process. When the apparatus encounters a restriction  
9 or obstruction, the second member (and the enlarged  
10 diameter portion thereof) moves in the direction of  
11 travel or load. As the enlarged diameter portion  
12 moves axially out of engagement with the inner face  
13 of the fingers, at least the sloping portions of the  
14 respective profiles on the enlarged diameter portion  
15 and the inner face of the fingers disengage. This  
16 allows the fingers to contract as they can move  
17 radially inward into the space created by axial  
18 movement of the enlarged diameter portion.

19

20 According to a second aspect of the present  
21 invention, there is provided apparatus for expanding  
22 an expandable member, the apparatus comprising a  
23 body, one or more radially movable portions, and  
24 force isolating means acting between the body and the  
25 or each radially moveable portion.

26

27 The force isolating means typically provides a  
28 biasing force to the or each radially moveable  
29 portion. The force required to move the or each  
30 radially moveable portion inwards is typically

1 greater than the biasing force of the force isolating  
2 means.

3  
4 Force applied to the body is typically transmitted to  
5 the or each radially moveable portion through the  
6 isolating means, and the radial position of the or  
7 each radially movable portion is typically at least  
8 partially controlled by the biasing force of the  
9 force isolating means. Force applied to the body can  
10 be isolated from the or each radially moveable  
11 portion by the force isolating means.

12  
13 The isolating means typically comprises a resilient  
14 member that allows relative movement between the body  
15 and the or each radially moveable portion, preferably  
16 in an axial direction. The resilient member may  
17 comprise a spring. The resilient member typically  
18 has a biasing force that is greater than a maximum  
19 load that will be applied to the apparatus. Thus,  
20 when the maximum load is reached and exceeded, the  
21 biasing force of the resilient member is overcome,  
22 and the resilient member deforms (e.g. extends or  
23 contracts) in the direction of the load.

24  
25 Alternatively, the isolating means comprises a fluid  
26 chamber that is in communication with the or each  
27 radially moveable portion. The fluid chamber is  
28 preferably in fluid communication with a spring  
29 means. The spring means typically comprises a first  
30 chamber, a floating piston in communication with the  
31 first chamber, and a second chamber in communication

1 with the piston. The first chamber typically  
2 contains fluid and is in fluid communication with the  
3 fluid chamber that is in communication with the or  
4 each radially moveable portion. The second chamber  
5 typically includes a spring. The spring may be  
6 mechanical, hydraulic, pneumatic or the like.

7  
8 In this embodiment, as the radially moveable portions  
9 are forced inward due to a restriction, they act on  
10 the fluid in the fluid chamber, forcing the fluid  
11 into the first chamber. The displacement of fluid  
12 causes the piston to compress the spring in the  
13 second chamber and this allows the radially moveable  
14 portions to move inwards, thus passing the  
15 restriction. Once the restriction has been passed,  
16 the spring extends forcing fluid in the first chamber  
17 to be transferred to the fluid chambers, thus forcing  
18 the radially moveable portions outwards.

19  
20 The biasing force of the force isolating means is  
21 typically provided by the spring. Optionally, the  
22 biasing force of the spring may be varied.

23  
24 In an alternative embodiment, the isolating means  
25 comprises a hydraulic spring. The hydraulic spring  
26 typically comprises an inflatable element that is in  
27 fluid communication with a fluid chamber. The fluid  
28 chamber is typically filled with a fluid (e.g. oil)  
29 that is typically incompressible. The fluid in the  
30 fluid chamber acts on a floating piston that is

1 located in a second chamber. The second chamber is  
2 typically filled with a fluid, preferably gas.

3  
4 In this embodiment, as the radially moveable portions  
5 are forced inwards due to a restriction, they act on  
6 the fluid in the inflatable element, forcing fluid  
7 into the fluid chamber. The displacement of fluid  
8 into the fluid chamber acts on the piston, causing it  
9 to compress the fluid in the second chamber. This  
10 allows the radially moveable portions to move  
11 inwards, thus passing the restriction. Once the  
12 restriction has been passed, the fluid in the second  
13 chamber expands, forcing the piston to act on the  
14 fluid in the fluid chamber, the fluid typically being  
15 transferred to the inflatable element, thus forcing  
16 the radially moveable portions outwards.

17  
18 The biasing force of the force isolating means is  
19 typically provided by the fluid in the second  
20 chamber. Optionally, the biasing force can be  
21 varied, typically by varying the amount of fluid in  
22 the second chamber.

23  
24 The body may comprise a cylindrical member, and the  
25 or each radially moveable portion is typically  
26 pivotably mounted to the body.

27  
28 The apparatus optionally includes a second member  
29 that typically comprises a shaft. The shaft  
30 typically houses at least a portion of the isolating  
31 means. In one embodiment, the shaft houses the fluid

1 chamber that is in communication with the or each  
2 radially moveable portion, and the spring means. In  
3 an alternative embodiment, the shaft houses a  
4 hydraulic spring.

5  
6 A second end of the shaft is typically provided with  
7 attachment means for attaching the apparatus to a  
8 drill string or the like, although the attachment  
9 means may be provided on the body. The attachment  
10 means may comprise any conventional means such as  
11 screw threads (e.g. box and/or pin connections) or  
12 the like.

13  
14 The or each radially moveable portion typically  
15 comprises one or more fingers. The or each finger is  
16 typically coupled to the body so that they can move  
17 in a radial and/or axial direction. Thus, the or  
18 each finger can expand or contract to adjust an outer  
19 diameter of the apparatus. Typically, the or each  
20 finger is held in a radially expanded position by the  
21 fluid in the fluid chamber or the inflatable element.  
22 In this position, the fluid in the inflatable element  
23 or the fluid chamber abuts against an inner surface  
24 of the or each finger and prevents them from moving  
25 radially inward. However, the fingers can move  
26 radially inward against the biasing force of the  
27 hydraulic spring or the spring means, provided that  
28 the force acting on the fingers produced by  
29 engagement with the restriction is sufficient to  
30 overcome the biasing force.

31

1 The or each finger is typically pivotally coupled to  
2 the housing using a pivot, such as a pivot pin, hinge  
3 or the like. Optionally, a biasing means may be  
4 provided to bias the fingers radially outward. The  
5 biasing means may comprise a torsion spring that is  
6 positioned at the pivot.

7  
8 An outer face of the or each finger typically defines  
9 a cone. The outer faces of the or each finger are  
10 typically angled so that the cone formed thereby  
11 faces in the direction of travel of the apparatus.  
12 Thus, as the apparatus is moved in the direction of  
13 travel, the outer faces engage an inner wall of the  
14 expandable member or the like to expand the  
15 expandable member.

16  
17 Optionally, the outer faces may include a second  
18 sloping face that is angled so that the apparatus can  
19 expand the inner diameter of the tubular when moved  
20 in the opposite direction to the normal direction of  
21 travel. In this embodiment, there is provided a  
22 double-sided cone that can be used in either  
23 direction of travel to expand the expandable member.

24  
25 The expandable member can be any tubular member, such  
26 as casing, liner, drill pipe etc, and other such  
27 downhole tubulars.

28  
29 Embodiments of the present invention shall now be  
30 described, by way of example only, with reference to  
31 the accompanying drawings, in which:-

1           Fig. 1 is a cross-sectional elevation of a first  
2           embodiment of apparatus for radially expanding  
3           an expandable member;  
4           Fig. 2 is a view of the apparatus of Fig. 1 in a  
5           contracted configuration;  
6           Fig. 3 is a cross-sectional elevation of a  
7           second embodiment of apparatus for radially  
8           expanding an expandable member;  
9           Fig. 4 is a view of the apparatus of Fig. 3 in a  
10          contracted configuration;  
11          Fig. 5 is a graph showing a typical relationship  
12          between an expanding diameter of the apparatus  
13          of Figs 1 and 2 with the pulling force applied  
14          to the apparatus;  
15          Fig. 6 is a graph showing a typical relationship  
16          between an expanding diameter of the apparatus  
17          of Figs 3 and 4 with the pulling force applied  
18          to the apparatus and/or where the apparatus of  
19          Figs 1 and 2 is provided with a pre-tensioning  
20          means;  
21          Fig. 7a is a cross-sectional view of a third  
22          embodiment of apparatus for radially expanding  
23          an expandable member;  
24          Fig. 7b is an enlarged view of a portion of the  
25          apparatus of Fig. 7a;  
26          Fig. 7c is a graph showing a relationship  
27          between an expanding diameter of the apparatus  
28          of Figs 7a and 7b with the pulling force applied  
29          to the apparatus; and



1        Fig. 8a is a cross-sectional elevation of part  
2        of a fourth embodiment of apparatus for radially  
3        expanding an expandable member; and  
4        Fig. 8b is an enlarged view of a portion of the  
5        apparatus of Fig. 8a.

6  
7        Referring to the drawings, Fig. 1 shows a part cross-  
8        sectional elevation of an exemplary embodiment of  
9        apparatus, generally designated 10, for expanding an  
10       expandable member such as liners, casings, drill pipe  
11       and other such downhole tubulars. It should be noted  
12       that the terms "upper" and "lower" will be used  
13       herein with reference to the orientation of the  
14       apparatus 10 as shown in Fig. 1, but this is  
15       arbitrary.

16  
17       The expandable member may comprise any tubular, such  
18       as drill pipe, liner, casing or the like and is  
19       typically of a ductile material so that it can be  
20       radially expanded. The radial expansion of the  
21       expandable member typically causes the member to  
22       undergo plastic and/or elastic deformation to  
23       increase its inner and outer diameters.

24  
25       Apparatus 10 includes a housing 12 that is typically  
26       cylindrical, although other shapes and configurations  
27       are also contemplated. Housing 12 is provided with a  
28       blind bore 14.

29  
30       A shaft 16 is located within the bore 14 and attached  
31       to the housing 12 via a resilient member, which in

1 this embodiment comprises a spring 18, provided at  
2 the (blind) lower end of the bore 14. Any member  
3 that has resilient properties, i.e. it can regain its  
4 original shape and configuration after being  
5 stretched, compressed or otherwise deformed, can be  
6 used. The purpose of the resilient member 18 is to  
7 absorb an axial pulling force (represented by arrows  
8 20 in Fig. 1) applied to the shaft 16 during  
9 expansion, and to isolate that axial force from a  
10 radial expansion force that is applied to a plurality  
11 of cone segments or fingers 22, as will be described.

12  
13 The biasing force of the resilient member 18 (e.g.  
14 the spring) is preferably rated at a higher level  
15 than the anticipated maximum pulling force or load 20  
16 applied to the apparatus 10 in the axial direction.  
17 Thus, in normal use, the resilient member 18 will not  
18 be fully extended, provided that the maximum load 20  
19 does not exceed the biasing force of the spring 18.  
20 However, when the axial load 20 exceeds the biasing  
21 force of the spring 18 (i.e. the anticipated maximum  
22 pulling force in the axial direction overcomes the  
23 biasing force of spring 18), the spring 18 extends  
24 (Fig. 2), as will be described.

25  
26 Shaft 16 is provided with attachment means (not  
27 shown) at an upper portion 16u that is used to couple  
28 the apparatus 10 to a drill string or the like. The  
29 attachment means may comprise any conventional  
30 coupling, such as screw threads (e.g. a pin and/or  
31 box connection) or the like.

1  
2 Shaft 16 is also provided with a central bore 16b for  
3 the passage of fluids therethrough. Similarly,  
4 housing 12 is provided with a bore 12b at the lower  
5 end thereof so that fluid can pass from above to  
6 below the apparatus 10, or vice versa. This  
7 facilitates the circulation of fluids within the  
8 borehole, both when the apparatus 10 is being run in,  
9 and also whilst it is in use. Optionally, fluid  
10 pressure may be used to propel the apparatus 10, as  
11 will be described.

12  
13 The shaft 16 is further provided with a reduced  
14 diameter portion 16r that facilitates inward movement  
15 of the fingers 22, as will be described.

16  
17 The plurality of cone segments or fingers 22 (only  
18 two shown in Fig. 1) are pivotally coupled to the  
19 housing 12 around its circumference, using, for  
20 example, a pivot pin 24 or the like. It is preferred  
21 that the fingers 22 are capable of movement in a  
22 radial direction so that they can assume either a  
23 radially expanded configuration (shown in Fig. 1), or  
24 a retracted configuration (shown in Fig. 2).  
25 Optionally, the fingers 22 may also be capable of  
26 movement in an axial direction.

27  
28 In the radially expanded configuration, as shown in  
29 Fig. 1, the fingers 22 are extended so that they form  
30 an outer diameter that approximates the final  
31 (expanded) inner diameter of the expandable member,

1 to effect radial expansion thereof. In the retracted  
2 configuration shown in Fig. 2, the fingers 22 assume  
3 an outer diameter that is less than the nominal  
4 (unexpanded) inner diameter of the expandable member,  
5 and typically less than an outer diameter of the  
6 housing 12, although this is not essential. Thus,  
7 when in the expanded configuration, the fingers 22  
8 expand the expandable member. In the retracted  
9 configuration, the fingers 22 can bypass restrictions  
10 within the expandable member or restrictions that  
11 protrude into the path of the apparatus 10 from, for  
12 example, the surrounding formation, that would arrest  
13 the travel of the apparatus 10.

14

15 A plurality of windows or slots 25 are provided in  
16 the housing 12 to accommodate the radial movement of  
17 the fingers 22. The windows 25 may also be  
18 dimensioned to allow for movement of the fingers 22  
19 in the axial direction also.

20

21 The shaft 16 is provided with an enlarged diameter  
22 portion 16e that has an outer profile corresponding  
23 to an inner profile of the fingers 22. In  
24 particular, the outer profile of the enlarged portion  
25 16e has a flat portion 16f, and a sloping portion,  
26 16s. Correspondingly, the inner surface of the  
27 fingers 22 has a flat portion 22f, and a sloping  
28 portion 22s.

29

30 In normal use, the respective portions 16f, 22f, 16s,  
31 22s engage so that the shaft 16 prevents the fingers

1 22 from moving radially inward, and can also provide  
2 support to the fingers 22 during the expansion  
3 process. It is preferred, but not essential, that  
4 the angle of the sloping portions 16s, 22s is  
5 relatively shallow. The shallow angle provides a  
6 larger contact area for the compressive force applied  
7 through the fingers 22 to the shaft 16 at an angle  
8 perpendicular to the sloping portion 22s, as movement  
9 of the fingers 22 past the obstruction will push the  
10 fingers 22 radially inward. To overcome this  
11 compressive force, a torsion spring or any other  
12 biasing means can be used, for example at the pivots  
13 24, to bias the fingers radially outward. The  
14 biasing force of the torsion spring would be at least  
15 equal to the normal compressive force applied to the  
16 fingers 22 when an obstruction is encountered.

17  
18 It should be noted that the angle of the face 16s to  
19 the axis of the apparatus 10 can be adjusted to  
20 provide a gearing effect. With the surface 16s at a  
21 shallow angle that is close to parallel to the axis  
22 of the shaft 16, the force required to move the shaft  
23 16 and extend the spring 18 is high; whereas with the  
24 surface 16s at a steep angle near perpendicular to  
25 the axis, the shaft 16 can be induced to move and  
26 extend the spring 18 under a fairly small force  
27 applied through the fingers 22.

28  
29 The expandable member is expanded by an outer face 26  
30 of the fingers 22 that together with an upper portion  
31 26u form an expansion cone made up from the

1 individual fingers 22, each tapering towards the  
2 direction of travel from a widest point 28. When the  
3 fingers 22 are in the radially extended position, as  
4 shown in Fig. 1, the upper portions 26u of the faces  
5 26 form a first expansion cone, the apex of which  
6 points in the direction of travel of the apparatus  
7 10. It is preferred, but not essential, that the  
8 upper portions 26u of the outer faces 26 form a  
9 continuous surface to expand the expandable member or  
10 the like across the entire inner circumference  
11 thereof.

12

13 In the Fig. 1 embodiment, each finger 22 has a lower  
14 portion 26l that tapers from the widest point 28  
15 radially inwards towards the other end of the  
16 fingers. Thus, faces 27 on the lower portion 26l  
17 form a second expansion cone that can be used to  
18 expand the expandable member in the reverse direction  
19 (that is the direction opposite to the normal  
20 direction of travel). It should be noted that the  
21 provision of the second expansion cone formed by the  
22 faces 27 on the lower portion 26l is optional.

23

24 The widest point 28 is created at the junction  
25 between the upper and lower outer faces 26, 27.

26

27 In use, the apparatus 10 is attached to a drill  
28 string or the like using the attachment means  
29 typically located at the upper end 16u of the shaft  
30 16.

31

1 An expandable member that is to be located in the  
2 borehole and then expanded can be positioned on top  
3 of the apparatus 10. That is, the expandable member  
4 can be rested on the upper face 26u of the fingers 22  
5 whilst the drill string is inserted into the  
6 borehole. The expandable member is then anchored  
7 into place, for example using an anchoring device  
8 (e.g. a packer) at the top or bottom of the  
9 expandable member, depending on the direction of  
10 propulsion of the apparatus 10.

11

12 The apparatus 10 is generally pulled up through the  
13 expandable member using the drill string so that the  
14 upper faces 26u on the fingers 22 radially expands  
15 the inner surface of the expandable member. In this  
16 case, the expandable member would typically be  
17 anchored at a lower end thereof. The expandable  
18 member is preferably expanded sufficiently so that  
19 the outer surface thereof presses against the  
20 formation of the borehole, or the pre-installed  
21 portion of expandable member, casing etc.

22

23 Referring to Fig. 2, if during the expansion process,  
24 the apparatus 10 becomes stuck, for example due to a  
25 solid protrusion on or in the expandable member into  
26 the path of the apparatus 10, or a solid protrusion  
27 in the surrounding formation that extends into the  
28 path of the apparatus 10, the spring 18 extends in  
29 the axial direction because the force that is used to  
30 pull the apparatus 10 through the expandable member  
31 increases, the apparatus 10 stops moving at the

1 protrusion, and the increased force will be greater  
2 than the force required to overcome the biasing force  
3 of the spring 18. As the spring 18 expands, the  
4 shaft 16 and in particular the enlarged portion 16e  
5 is moved upwardly in the axial direction as shown in  
6 Fig. 2.  
7  
8 As shaft 16 moves upwards and the housing 12 is  
9 arrested at the protrusion, the fingers 22 are no  
10 longer supported by the enlarged diameter portion 16e  
11 and can move radially inward. This inward movement  
12 of at least one of the fingers 22 can allow the  
13 apparatus 10 to bypass the restriction. This process  
14 can be aided if the fingers 22 are capable of some  
15 axial movement in the opposite direction to the  
16 movement of the shaft 16. The axial movement can be  
17 aided by providing elongated slots that extend in the  
18 axial direction at the pivots 24. When the fingers  
19 22 encounter a restriction at the expansion point 28,  
20 the axial pulling force 20 will tend to pull the  
21 apparatus 10 upwardly. If the pivot pins 24 are  
22 located in axial slots, the fingers 22 can move  
23 axially downwards in the slots relative to the  
24 housing 12, further separating the enlarged diameter  
25 portion 16e and the fingers 22 and allowing the  
26 fingers 22 to move radially inward.  
27  
28 As the protrusion is passed, the spring 18 contracts  
29 because it has a higher biasing force than the normal  
30 pulling force 20 applied to the apparatus 10, and the  
31 fingers 22 move radially outward to the position



1 shown in Fig. 1 due to the engagement of the enlarged  
2 diameter portion 16e with the fingers 22, and/or the  
3 biasing force applied to the fingers 22 (e.g. at the  
4 pivot pins 24).

5  
6 Thus, as the fingers 22 can contract by moving  
7 radially inwards (and optionally axially), the  
8 apparatus 10 does not become permanently stuck,  
9 thereby obviating having to retrieve the apparatus 10  
10 from the borehole. This provides an advantage in  
11 that no rig time is lost in having to perform a  
12 fishing operation to retrieve the stuck expander  
13 device. Also, the apparatus 10 resets itself back  
14 into expansion mode due to the biasing force of the  
15 spring 18. Thus, it can bypass any number of  
16 restrictions within the borehole without having to be  
17 retrieved therefrom and manually reset.

18  
19 It should be noted that reversing the direction of  
20 travel of the apparatus 10 could aid in freeing it,  
21 as the fingers 22 will be pushed radially inward due  
22 to contact with the restriction.

23  
24 Hydraulic or other types of fluid pressure may be  
25 used to propel the apparatus 10. In this particular  
26 embodiment, the apparatus 10 would be turned upside  
27 down with respect to the orientation shown in Figs 1  
28 and 2. Fluid pressure can then be applied to the  
29 apparatus 10, at least a portion of which preferably  
30 acts directly on the end of shaft 16, typically via a  
31 throughbore 12b in housing 12. The bore 16b through

1 the shaft 16 is generally not required for this  
2 particular embodiment. However, the bore 16b can be  
3 provided with a restriction (e.g. a blind bore) so  
4 that fluid pressure in the bore 16b can be contained  
5 to aid movement of the shaft 16.

6  
7 It will be appreciated that bore 12b can be made  
8 larger or smaller to adjust the pressure that is  
9 applied to the end of the shaft 16. The end of the  
10 shaft 16 could be provided with a flared end  
11 (optionally with seals) that engages bore 14 of the  
12 housing 12.

13  
14 Fluid pressure would be applied to housing 12, and a  
15 portion of this pressure would act directly on the  
16 shaft 16 via bore 12b. The contact between the upper  
17 faces 26u (which would be lower faces with the  
18 apparatus 10 turned upside down) with the expandable  
19 member that is to be expanded would create a seal for  
20 the fluid pressure. The apparatus 10 could thus be  
21 used to expand the expandable member from the top  
22 down. This is advantageous, as no rig would be  
23 required to push or pull the apparatus 10 (only fluid  
24 pressure), but the apparatus 10 would generally need  
25 to be retrieved from the borehole once the expandable  
26 member has been expanded.

27  
28 As the apparatus 10 is propelled through the  
29 expandable member using fluid pressure, the upper  
30 faces 26u of the fingers 22 form an expansion cone  
31 that will radially expand the expandable member. As

1 with the previous embodiment, if during the expansion  
2 process the apparatus 10 becomes stuck, the spring 18  
3 extends in the axial direction because the fluid  
4 pressure applied to the shaft 16 increases, but the  
5 apparatus 10 stops moving at the protrusion, and the  
6 increased force will be greater than the force  
7 required to overcome the biasing force of the spring  
8 18. The spring 18 expands, and the shaft 16, in  
9 particular the enlarged diameter portion 16e, is  
10 moved downwardly in the axial direction. The  
11 downward movement of shaft 16 allows the fingers 22  
12 to move inward as they are no longer supported by the  
13 enlarged diameter portion 16e. This inward movement  
14 of at least one of the fingers 22 can allow the  
15 apparatus 10 to bypass the restriction.

16  
17 Where the bore 16b is provided with a restriction,  
18 the build up of fluid pressure caused by the arrest  
19 in the travel of the apparatus 10 will aid in moving  
20 the shaft 16 against the bias force of spring 18, so  
21 that the enlarged portion 16e moves out of contact  
22 with the fingers 22, allowing one or more fingers 22  
23 to move radially inward.

24  
25 As the protrusion is passed, the spring 18 contracts  
26 because it has a higher biasing force than the force  
27 of the fluid pressure applied to the apparatus 10,  
28 and the fingers 22 move radially outward due to the  
29 engagement of the enlarged diameter portion 16e with  
30 the fingers 22, and/or the biasing force applied to  
31 the fingers 22 (e.g. at the pivot pins 24).

1  
2 Alternatively, the shaft 16 in this embodiment could  
3 be attached to the housing 12 above the level of the  
4 fingers 22, for example using a spring. The spring  
5 would typically be a compressive spring where in its  
6 normal state the spring is extended, but can be  
7 compressed.  
8  
9 As fluid pressure is applied to the bottom of shaft  
10 16 and/or the housing 12, the apparatus is moved  
11 through the expandable member to radially expand the  
12 expandable member (typically using upper faces 26u).  
13 When the apparatus meets a restriction in its path,  
14 the travel of the apparatus is arrested at which  
15 point the fluid pressure acts on shaft 16 thereby  
16 compressing the spring. The compression of the  
17 spring allows the shaft 16 to move axially and thus  
18 the enlarged portion 16e moves out of contact with  
19 the fingers 22 allowing them to move radially inwards  
20 and thus by-pass the restriction. Once the  
21 restriction is passed, the spring extends to its  
22 normal configuration and expansion of the expandable  
23 member continues.  
24  
25 It will be appreciated that the force that normally  
26 biases the spring to move the shaft 16 away from the  
27 housing can be selected to provide a pre-tensioning  
28 means, as described below.  
29  
30 It should be noted that as the fingers 22 are  
31 independently attached to the housing 12, partial

1 collapse of the cone formed thereby is possible.  
2 This may result in, for example, an elliptical shape  
3 at the widest point 28.

4  
5 Figs 3 and 4 show an alternative embodiment of  
6 apparatus according to the present invention,  
7 generally designated 100. Apparatus 100 is similar  
8 to apparatus 10 (Figs 1 and 2) and includes a housing  
9 112 (shown in part cross-section) that is typically  
10 cylindrical, although other shapes and configurations  
11 are also contemplated. The housing 112 is provided  
12 with an internal cavity or bore 114 in which a shaft  
13 116 is partially located.

14  
15 An upper portion 116u of the shaft 116 is typically  
16 provided with conventional coupling means (e.g. screw  
17 threads) so that the apparatus 100 can be coupled to  
18 a drill string, coiled tubing string, wireline or the  
19 like. Thus, the apparatus 100 can be pulled through  
20 an expandable member 150 that is to be expanded.

21  
22 Shaft 116 is capable of longitudinal movement within  
23 the cavity 114 relative to housing 112 and is biased  
24 to the position shown in Fig. 3 by a resilient  
25 member, which in this embodiment comprises a spring  
26 118. Spring 118 is located below the housing 112,  
27 typically between a lower face 112l of the housing  
28 112 and a lower face 116l of the shaft 116. It  
29 should be noted that spring 118 is merely exemplary,  
30 and any member that has resilient properties, i.e. it  
31 can regain its original shape and configuration after

1 being stretched, compressed or otherwise deformed,  
2 can be used. In the embodiment shown in Figs 3 and  
3 4, the spring 118 is typically normally extended.

4  
5 As with the previous embodiment, the purpose of the  
6 spring 118 is to absorb an axial pulling or  
7 propulsive force applied to the shaft 116 during the  
8 radial expansion process (as described below), and to  
9 isolate that axial pulling or propulsive force from a  
10 radial expansion force that is applied to a plurality  
11 of cone segments or fingers 122, as will be  
12 described.

13  
14 The biasing force of the spring 118 is preferably  
15 rated at a higher level than the anticipated maximum  
16 pulling or propulsive force applied to the apparatus  
17 100 in the axial direction. Thus, in normal use, the  
18 spring 118 is typically fully extended, provided that  
19 the maximum pulling or propulsive force does not  
20 exceed the biasing force of the spring 118. However,  
21 when the axial pulling or propulsive force exceeds  
22 the biasing force of the spring 118 (i.e. the  
23 anticipated maximum pulling or pushing force in the  
24 axial direction overcomes the biasing force of spring  
25 118), the spring 118 contracts (Fig. 4), as will be  
26 described.

27  
28 The embodiment shown in Figs 3 and 4 can be propelled  
29 through the casing using hydraulic or other fluid  
30 pressure. An optional stop 120 is provided that is  
31 engageable with a lower end of the shaft 116. Fluid

1 acts on a lower surface 1201 of the stop 120 and thus  
2 propels the apparatus 100 upwardly, providing that  
3 the force of fluid pressure is sufficient. The stop  
4 120 can be provided with sealing means that seal  
5 between outer surfaces 1200 of the stop 120 and the  
6 inner surface of the expandable member 150 that is to  
7 be radially expanded.

8

9 In this particular embodiment, the shaft 116 and the  
10 optional stop 120 are not provided with throughbores  
11 (unlike the previous embodiment) although they may be  
12 if required. The throughbores could facilitate the  
13 circulation of fluids within the borehole, both when  
14 the apparatus 100 is being run in, and also whilst it  
15 is in use.

16

17 The plurality of cone segments or fingers 122 (only  
18 one shown in Fig. 1) are pivotally coupled to the  
19 housing 112 around its circumference, using, for  
20 example, a pivot pin 124 or the like. It is  
21 preferred that the fingers 122 are capable of  
22 movement in a radial direction so that they can  
23 assume either a radially expanded configuration  
24 (shown in Fig. 3), or a retracted configuration  
25 (shown in Fig. 4). Optionally, the fingers 122 may  
26 also be capable of movement in an axial direction.

27

28 In the radially expanded configuration, as shown in  
29 Fig. 3, the fingers 122 are extended so that they  
30 form an outer diameter that approximates the final  
31 (expanded) inner diameter of the expandable member

1 150, casing etc to effect radial expansion thereof.  
2 In the retracted configuration shown in Fig. 4, the  
3 fingers 122 assume an outer diameter that is less  
4 than the nominal (unexpanded) inner diameter of the  
5 expandable member 150, and typically less than an  
6 outer diameter of the housing 112, although this is  
7 not essential. Thus, when in the expanded  
8 configuration, the fingers 122 expand the expandable  
9 member 150. In the retracted configuration, the  
10 fingers 122 can bypass restrictions within the  
11 expandable member 150 or restrictions that protrude  
12 into the path of the apparatus 100 from, for example,  
13 the surrounding formation, that would arrest the  
14 travel of the apparatus 100.

15

16 A plurality of windows or slots 125 are provided in  
17 the housing 112 to accommodate the radial movement of  
18 the fingers 122. The windows 125 may also be  
19 dimensioned to allow for movement of the fingers 122  
20 in the axial direction.

21

22 As with the previous embodiment, shaft 116 is  
23 provided with an enlarged diameter portion 116e. The  
24 enlarged diameter portion 116e has a flat portion  
25 116f, and a sloping portion 116s. In this  
26 embodiment, the fingers 122 are provided with a  
27 rounded inner surface 122r that typically engages the  
28 flat surface 116f of the enlarged portion 116e during  
29 normal use (as shown in Fig. 3). Fingers 122 may  
30 have a similar inner profile to fingers 22.

31



1 In normal use, the rounded inner surface 122r engages  
2 the flat surface 116f so that the shaft 116 prevents  
3 the fingers 122 from moving radially inward, and can  
4 also provide support to the fingers 122 during the  
5 expansion process. As with the previous embodiment,  
6 a torsion spring or any other biasing means can be  
7 used, for example at the pivots 124, to bias the  
8 fingers 122 radially outward. The biasing force of  
9 the torsion spring would be at least equal to the  
10 normal compressive force applied to the fingers 122  
11 when an obstruction is encountered.

12  
13 The expandable member 150 is expanded by an outer  
14 face 126 of the fingers 122 that together with an  
15 upper portion 126u form an expansion cone made up  
16 from the individual fingers 122, each tapering  
17 towards the direction of travel from a widest point  
18 128. When the fingers 122 are in the radially  
19 extended position, as shown in Fig. 3, the upper  
20 portions 126u of the faces 126 form a first expansion  
21 cone, the apex of which points in the direction of  
22 travel of the apparatus 100. It is preferred, but  
23 not essential, that the upper portions 126u of the  
24 outer faces 126 form a continuous surface to expand  
25 the expandable member 150 or the like across the  
26 entire inner circumference thereof.

27  
28 In the Fig. 3 embodiment, each finger 122 has a lower  
29 portion 126l that tapers from the widest point 128  
30 radially inwards towards the other end of the  
31 fingers. Thus, faces 127 on the lower portion 126l

1 form a second expansion cone that can be used to  
2 expand the expandable member 150 in the reverse  
3 direction (that is the direction opposite to the  
4 normal direction of travel). It should be noted that  
5 the provision of the second expansion cone formed by  
6 the faces 127 on the lower portion 126l is optional.

7

8 The widest point 128 is created at the junction  
9 between the upper and lower outer faces 126, 127.

10

11 In use, the apparatus 100 may be attached to a drill  
12 string, coiled tubing string, wireline or the like.  
13 The expandable member 150 that is to be located in  
14 the borehole and then expanded can be positioned on  
15 top of the apparatus 100. That is, the expandable  
16 member 150 can be rested on the upper face 126u of  
17 the fingers 122 whilst the expandable member 150 or  
18 the like is inserted into the borehole. The  
19 expandable member 150 is then anchored into place,  
20 for example using an anchoring device (e.g. a packer)  
21 at the top or bottom of the expandable member 150,  
22 depending on the direction of motion of the apparatus  
23 100.

24

25 The apparatus 100 is pulled or propelled upwardly  
26 through the expandable member 150 ("upwardly" being  
27 arbitrary and with respect to the orientation of the  
28 apparatus 100 in Figs 3 and 4) using a drill string  
29 or the like to pull the apparatus 100, or by applying  
30 fluid pressure to the lower surface 120l of the stop  
31 120. The upper portions 126u on the fingers 122

1 radially expand the inner surface of the expandable  
2 member 150 as the apparatus 100 is pulled or  
3 propelled through the casing. In this case, the  
4 expandable member 150 would typically be anchored at  
5 or near a lower end thereof. The expandable member  
6 150 is preferably expanded sufficiently so that the  
7 outer surface of the expandable member 150 presses  
8 against the formation of the borehole, or the pre-  
9 installed portion of liner, casing etc.

10

11 Referring to Fig. 4, if during the expansion process,  
12 the apparatus 100 becomes stuck, for example due to a  
13 solid protrusion on or in the expandable member 150  
14 in the path of the apparatus 100, or a solid  
15 protrusion in the surrounding formation that extends  
16 into the path of the apparatus 100, the spring 118  
17 contracts in the axial direction because the pulling  
18 or fluid force that is used to pull or propel the  
19 apparatus 100 through the expandable member 150  
20 increases, the apparatus 100 stops moving at the  
21 protrusion, and the increased force will be greater  
22 than the force required to overcome the biasing force  
23 of the spring 118. As the spring 118 contracts, the  
24 shaft 116 and in particular the enlarged portion 116e  
25 is moved upwardly in the axial direction as shown in  
26 Fig. 4.

27

28 As shaft 116 moves upwards and the housing 112 is  
29 arrested at the protrusion, the fingers 122 are no  
30 longer supported by the enlarged diameter portion  
31 116e and can move radially inward. This inward

1 movement of at least one of the fingers 122 can allow  
2 the apparatus 100 to bypass the restriction. This  
3 process can be aided if the fingers 122 are capable  
4 of some axial movement in the opposite direction to  
5 the movement of the shaft 116. The axial movement  
6 can be aided by providing elongated slots that extend  
7 in the axial direction at the pivots 124. When the  
8 fingers 122 encounter a restriction at the widest  
9 point 128, the fluid propulsion will tend to push the  
10 apparatus 100 upwardly. If the pivot pins 124 are  
11 located in axial slots, the fingers 122 can move  
12 axially downwards in the slots relative to the  
13 housing 112, further separating the enlarged diameter  
14 portion 116e and the fingers 122 and allowing the  
15 fingers 122 to move radially inward.

16  
17 As the protrusion is passed, the spring 118 expands  
18 because it has a higher biasing force than the normal  
19 pulling or propulsive force applied to the apparatus  
20 100, and the fingers 122 move radially outward to the  
21 position shown in Fig. 3 due to the engagement of the  
22 enlarged diameter portion 116e with the fingers 122,  
23 and/or the biasing force applied to the fingers 122  
24 (e.g. at the pivot pins 124).

25  
26 Thus, as the fingers 122 can contract by moving  
27 radially inwards (and optionally axially), the  
28 apparatus 100 does not become permanently stuck,  
29 thereby obviating having to retrieve the apparatus  
30 100 from the borehole. This provides an advantage in  
31 that no rig time is lost in having to perform a

1 fishing operation to retrieve the stuck expander  
2 device. Also, the apparatus 100 resets itself back  
3 into expansion mode due to the biasing force of the  
4 spring 118. Thus, it can bypass any number of  
5 restrictions within the borehole without having to be  
6 retrieved therefrom and manually reset.

7  
8 It should be noted that as the fingers 122 are  
9 independently attached to the housing 112, partial  
10 collapse of the cone formed thereby is possible.  
11 This may result in, for example, an elliptical shape  
12 at the widest point 128.

13  
14 In this particular embodiment, setting weight on the  
15 shaft 116 from the drill string, coiled tubing string  
16 etc from above can aid in resetting the apparatus 100  
17 and thus open up the fingers 122 to form the  
18 expansion cone.

19  
20 The axial pulling force, represented by  $F_a$  in Figs 3  
21 to 6, is typically directly related to the diameter  
22 of the apparatus 100 at the widest point 128 of the  
23 fingers 122. Referring to Fig. 5, there is shown the  
24 general relationship between the diameter at the  
25 widest point (represented in Figs 5 and 6 as  $\phi 3$ ) and  
26 the axial pulling force  $F_a$ . As can be seen from Fig.  
27 5, the diameter at the widest point reduces linearly  
28 as the pulling force  $F_a$  increases.

29  
30 However, it is preferred that the apparatus 100 is  
31 provided with a means that prevents the fingers 122

1 from moving inward until a given value of pulling  
2 force  $F_0$  is achieved or preferably exceeded.

3

4 Fig. 6 shows a pre-tensioning force  $F_0$  that can be  
5 applied to the apparatus 100, where  $F_0$  is typically  
6 greater than or equal to  $F_0$ . Thus, the pre-  
7 tensioning allows for a certain amount of travel of  
8 the shaft 116 in the axial direction before the  
9 fingers 122 can move inwards.

10

11 With the embodiment shown in Figs 3 and 4, a distance  
12 a is provided between the nominal engagement point of  
13 the rounded face 122r with the enlarged diameter  
14 portion 116e and the point where the enlarged  
15 diameter begins to reduce down to the nominal  
16 diameter of the shaft 116. The distance a  
17 facilitates normal force variations so that the  
18 fingers 122 do not collapse unless the pulling force  
19 or build-up of fluid pressure on the stop 120 is  
20 sufficient to move the shaft 116 upwards by a  
21 distance that exceeds distance a. Thus, the distance  
22 a effectively provides a pre-tensioning force as the  
23 shaft 116 can tolerate force variations until it is  
24 pulled upwards by a distance that exceeds distance a.

25

26 It will be noted that there is a relationship between  
27 the slope  $\beta$  and the length c (Figs 3 and 4) and these  
28 are connected by the change in outer diameter of the  
29 upper expansion cone formed by faces 126. The force  
30 required to restore the expansion cone to its  
31 original configuration where it expands the

1 expandable member 150 decreases as the slope  $\beta$   
2 increases. This is similar to the gearing effect of  
3 Figs 1 and 2.

4  
5 Fig. 7 shows a further alternative embodiment of  
6 apparatus according to the present invention. In the  
7 embodiment shown in Fig. 7, each finger 222 has a  
8 fixed piston 280 associated with it. The fixed  
9 piston 280 has an internal bore 280b that allows  
10 pressurised fluid from a reservoir, generally  
11 designated 282, located within the shaft 216 to flow  
12 through the piston 280 and collect in a chamber 284  
13 behind the finger 222.

14  
15 The reservoir 282 includes a fluid-filled chamber 286  
16 that has a piston 288 located above the chamber 286,  
17 and a damping spring 290 above the piston 288. The  
18 chamber 286 communicates with the chambers 284 behind  
19 the fingers 222 via connecting channels 292.

20  
21 In the Fig. 7 embodiment, the apparatus 200 is moved  
22 upwards by applying a pulling force  $F_a$  to the shaft  
23 216 as before. If the apparatus 200 encounters a  
24 restriction or resistance to upward movement, the  
25 fingers 222 that are mounted on pivots 224 move  
26 inwards. The inward movement of the fingers 222 acts  
27 on the fluid chamber 284 causing the fluid therein to  
28 be pushed inwardly into the channels 292, thus  
29 forming a radial piston. This inward movement causes  
30 the fluid pressure in the channels 292 and chamber  
31 286 to increase and the damping spring 290 absorbs

1 the increase in pressure, allowing the fingers 222 to  
2 move inwards so that the restriction can be passed.  
3 The damping spring 290 can be any conventional  
4 spring, such as gas, mechanical etc. Once the  
5 restriction has passed, the fluid pressure reduces  
6 and the bias force of the damping spring 290 causes  
7 the fingers 222 to expand to their nominal expansion  
8 diameter by forcing fluid out of the chamber 288 into  
9 the channels 292 and into the chamber 284 behind the  
10 fingers 222.

11

12 It is possible with the embodiment shown in Fig. 7 to  
13 control the fluid pressure in the chambers 286 and  
14 284 from the surface. Thus, the apparatus 200 can be  
15 run into an expandable member that is to be expanded  
16 in an unexpanded configuration. Once the apparatus  
17 200 has reached its intended location within the pre-  
18 installed casing, liner etc., fluid pressure in the  
19 apparatus 200 can be increased causing the fingers  
20 222 to assume their expanded position and the  
21 apparatus 200 can be pulled upwards to radially  
22 expand the expandable member.

23

24 As with the previous embodiment, the biasing force  
25 ( $f_{\text{spring}}$ ) of the spring 290 can be chosen so that the  
26 fingers 222 remain extended until a predetermined  
27 pulling force  $F_e$  is exceeded (see Figs 7b and 7c).  
28 Thus, the fingers 222 will not fully collapse until  
29 the biasing force  $f_{\text{spring}}$  provided by the spring 290 is  
30 overcome. This will allow for small variations in



1 the movement of the fingers 222 during normal use  
2 without the fingers collapsing.

3  
4 Fig. 8 shows a further alternative embodiment of  
5 apparatus according to the present invention. The  
6 apparatus, generally designated 300, includes a  
7 plurality of blades 302 that are pivotally connected  
8 to a body 301, typically via pins 306. Referring to  
9 Fig. 8b, each blade 302a overlaps the previous blade  
10 302b and an outer surface of the blades 302 typically  
11 forms an expansion cone in use. It is preferred that  
12 each blade 302 is pivotally mounted independently of  
13 one another. The blades 302 may be restrained in the  
14 amount of outward pivotal movement by a restrainer  
15 303 that limits the outward movement of the blade 302  
16 by engaging one end thereof. The pivot pins 306 are  
17 typically provided at or near a leading edge of the  
18 apparatus 300.

19  
20 An inflatable element 304, such as a packer, is  
21 located under the blades 302, as shown in Fig. 8a.  
22 The inflatable element 304 is coupled to a hydraulic  
23 absorber, generally designated 308. The hydraulic  
24 absorber 308 includes an oil reservoir 310 that is in  
25 fluid communication with the inflatable element 304.  
26 A floating piston 312 is located beside the oil  
27 reservoir 310, the piston 312 being capable of axial  
28 movement within the hydraulic absorber 308. A gas  
29 accumulator 314 is located beside the floating piston  
30 312 and is typically filled with a gas.

31

1 In use, the inflatable element 304 is pressurised to  
2 a constant pressure that is required to move the  
3 blades 302 outwards to expand the expandable member  
4 etc. The compressibility of the gas in the gas  
5 accumulator 314 and the incompressibility of the oil  
6 in the oil reservoir 310 gives a spring effect where  
7 the radial or reactive force applied to the blades  
8 302 from the expansion process applies a collapsing  
9 force to the inflatable element 304. The increase in  
10 pressure in the inflatable element 304 causes an  
11 increase in pressure in the oil reservoir 310 and the  
12 oil acts against the floating piston 312, forcing it  
13 into the gas accumulator 314 (as the gas therein is  
14 compressible). The movement of the piston 312 allows  
15 the blade(s) 302 to move inward(s) and thus the  
16 restriction can be passed.

17  
18 The pressure within the system is typically kept  
19 constant, and thus when the restriction has been  
20 passed, the pressure in the inflatable element 304  
21 returns to its original value, as the pressure in the  
22 oil reservoir 310 reduces, allowing the gas in the  
23 accumulator 314 to expand and the piston 312 moves  
24 back to its original position, forcing oil into the  
25 inflatable element 304.

26  
27 The gas accumulator 314 could be pressurised at the  
28 surface using a gas line for example, or downhole  
29 using a system that is similar to the Baker Model E-4  
30 Wireline Pressure Setting Assembly (Product Number  
31 437-02). In this embodiment, an electric current is

1 used and transmitted through electric wireline, to  
2 ignite a power charge in a setting assembly. The  
3 setting assembly is slow-burning charge that releases  
4 a gas as it burns, thus building up pressure in the  
5 gas accumulator 314. Thus, the apparatus 300 can be  
6 inserted through the expandable member that is to be  
7 expanded in an unexpanded configuration, and then the  
8 inflatable element 304 expanded downhole by igniting  
9 the first charge that in turn ignites the power  
10 charge to build up the pressure in the gas  
11 accumulator 314. The gas pressure would then act on  
12 the piston 312, compressing the oil in the reservoir  
13 310 causing some of the oil to be transferred to the  
14 inflatable element 304 thus pivoting the blades 302  
15 outwardly, as shown in Fig. 8a to radially expand the  
16 expandable member etc.

17  
18 Embodiments of the present invention provide numerous  
19 advantages over prior art expander devices, such as  
20 the ability to bypass restrictions without becoming  
21 arrested. In certain embodiments, the fingers or  
22 blades that make up the expansion cone are capable of  
23 collapsing inwards so that the restriction can be  
24 passed. Thereafter, the fingers or blades are moved  
25 back to their expanded configuration so that the  
26 expansion process can continue.

27  
28 Modifications and improvements may be made to the  
29 foregoing without departing from the scope of the  
30 present invention.

1    CLAIMS

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

29

30

31

32

1. Apparatus for expanding an expandable member, the apparatus comprising a first member, one or more radially movable portions, a second member, and force isolating means acting between the first and second members.

2. Apparatus according to claim 1, wherein the first member comprises a housing with a blind bore.

3. Apparatus according to either preceding claim, wherein the second member comprises a shaft having a cone that bears against the radially movable portions.

4. Apparatus according to claim 3, wherein the shaft and cone can move axially with respect to the first member in and out of engagement with the radially movable portions.

5. Apparatus according to any preceding claim, wherein the radially movable portions are coupled to the first member so that they can move in a radial and/or axial direction.

6. Apparatus according to any one of claims 3 to 5, wherein the force isolating means comprises a spring.

7. Apparatus according to claim 6, wherein the radially movable portions are held in a radially

1 expanded position by the cone on the second member  
2 moving axially with respect to the first member to a  
3 first position in which the spring is contracted.

4

5 8. Apparatus according to claim 7, wherein the  
6 second member can move axially under an axial  
7 pulling force, and the cone can move to a second  
8 position that allows the radially movable portions  
9 to move radially inward to bypass a restriction.

10

11 9. Apparatus according to claim 7 or claim 8,  
12 wherein as the restriction is passed, the axial  
13 pulling force drops below a biasing force of the  
14 spring so that the spring contracts, and the cone  
15 moves into engagement with the radially movable  
16 portions causing them to move radially outward to  
17 the radially expanded position.

18

19 10. Apparatus according to any one of claims 7 to  
20 9, wherein the engagement of the radially movable  
21 portions with the restriction can cause them to move  
22 inwards against the cone thereby moving it to the  
23 second position in which the spring is extended.

24

25 11. Apparatus according to any preceding claim,  
26 wherein the radially movable portions are pivotally  
27 coupled to the first member.

28

29 12. Apparatus according to any preceding claim,  
30 wherein an outer face of the radially movable  
31 portions defines a cone.

32

1 13. Apparatus for expanding an expandable member,  
2 the apparatus comprising a body, one or more  
3 radially movable portions, and force isolating means  
4 acting between the body and the or each radially  
5 moveable portion.

6

7 14. Apparatus according to claim 13, wherein the  
8 force isolating means provides a biasing force to  
9 the or each radially moveable portion.

10

11 15. Apparatus according to claim 14, wherein a  
12 force required to move the or each radially moveable  
13 portion inwards is greater than the biasing force of  
14 the force isolating means.

15

16 16. Apparatus according to claim 14 or claim 15,  
17 wherein a radial position of the or each radially  
18 movable portion is at least partially controlled by  
19 the biasing force of the force isolating means.

20

21 17. Apparatus according to any one of claims 14 to  
22 16, wherein force applied to the body can be  
23 isolated from the or each radially moveable portion  
24 by the force isolating means.

25

26 18. Apparatus according to any one of claims 13 to  
27 17, wherein the force isolating means comprises a  
28 resilient member that allows relative movement  
29 between the body and the or each radially moveable  
30 portion.

31

1 19. Apparatus according to claim 18, wherein the  
2 relative movement between the body and the or each  
3 radially moveable portion is in an axial direction.  
4

5 20. Apparatus according to claim 18 or claim 19,  
6 wherein the resilient member has a biasing force  
7 that is greater than a maximum load that will be  
8 applied to the apparatus.  
9

10 21. Apparatus according to any one of claims 13 to  
11 17, wherein the force isolating means includes a  
12 fluid chamber that is in communication with the or  
13 each radially moveable portion, the fluid chamber  
14 being in fluid communication with a spring means.  
15

16 22. Apparatus according to claim 21, wherein the  
17 spring means comprises a first chamber, a floating  
18 piston in communication with the first chamber, and  
19 a second chamber in communication with the piston.  
20

21 23. Apparatus according to claim 22, wherein the  
22 first chamber contains fluid and is in fluid  
23 communication with the fluid chamber that is in  
24 communication with the or each radially moveable  
25 portion, and the second chamber includes a spring.  
26

27 24. Apparatus according to claim 23, wherein as the  
28 radially moveable portions are forced inward due to  
29 a restriction, they act on the fluid in the fluid  
30 chamber, forcing the fluid into the first chamber,  
31 wherein the displacement of fluid causes the  
32 floating piston to compress the spring in the second

1 chamber and this allows the radially moveable  
2 portions to move inwards, thus passing the  
3 restriction.

4

5 25. Apparatus according to claim 24, wherein once  
6 the restriction has been passed, the spring extends  
7 forcing fluid in the first chamber to be transferred  
8 to the fluid chambers, thus forcing the radially  
9 moveable portions outwards.

10

11 26. Apparatus according to any one of claims 13 to  
12 17, wherein the force isolating means comprises a  
13 hydraulic spring.

14

15 27. Apparatus according to claim 26, wherein the  
16 hydraulic spring includes an inflatable element that  
17 is in fluid communication with a fluid chamber.

18

19 28. Apparatus according to claim 27, wherein the  
20 fluid chamber is filled with a fluid that is  
21 incompressible.

22

23 29. Apparatus according to claim 27 or claim 28,  
24 wherein the fluid in the fluid chamber acts on a  
25 floating piston that is located in a second chamber.

26

27 30. Apparatus according to claim 29, wherein the  
28 second chamber is filled with a gas.

29

30 31. Apparatus according to claim 29 or claim 30,  
31 wherein as the radially moveable portions are forced  
32 inwards due to a restriction, they act on the fluid



1 in the inflatable element, forcing fluid into the  
2 fluid chamber, and the displacement of fluid into  
3 the fluid chamber acts on the piston, causing it to  
4 compress the fluid in the second chamber.

5  
6 32. Apparatus according to claim 31, wherein once  
7 the restriction has been passed, the fluid in the  
8 second chamber expands, forcing the piston to act on  
9 the fluid in the fluid chamber, the fluid being  
10 transferred to the inflatable element, thus forcing  
11 the radially moveable portions outwards.

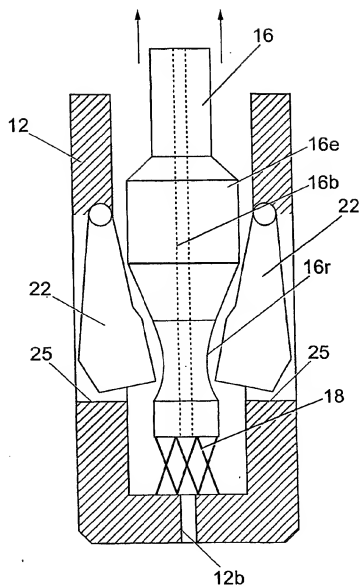
12  
13 33. Apparatus according to any one of claims 13 to  
14 32, wherein the or each radially moveable portion is  
15 pivotably mounted to the body.

16  
17 34. Apparatus according to any one of claims 13 to  
18 33, wherein the or each radially moveable portion  
19 comprises one or more fingers.

20  
21 35. Apparatus according to claim 34, wherein an  
22 outer face of the or each finger defines a cone.



2/7

*Fig. 2*

SUBSTITUTE SHEET (RULE 26)

3 / 7

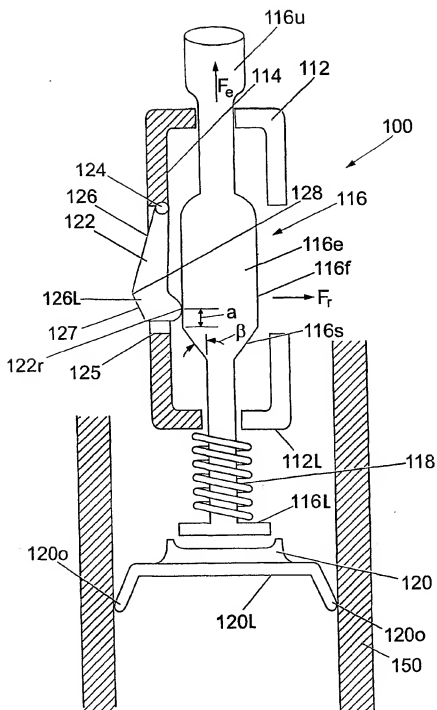


Fig. 3

SUBSTITUTE SHEET (RULE 26)

4/7

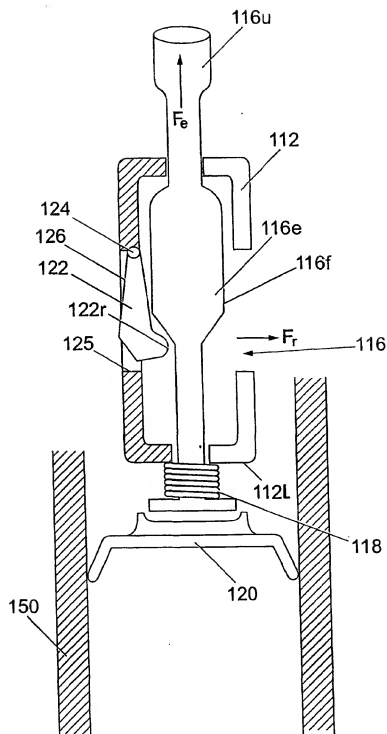


Fig. 4

SUBSTITUTE SHEET (RULE 26)

5/7

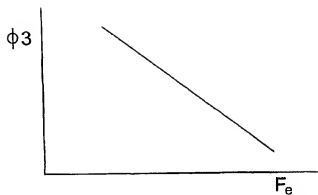


Fig. 5

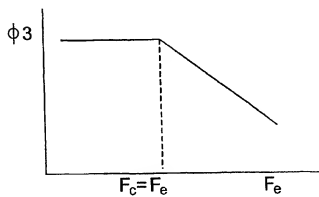


Fig. 6

SUBSTITUTE SHEET (RULE 26)

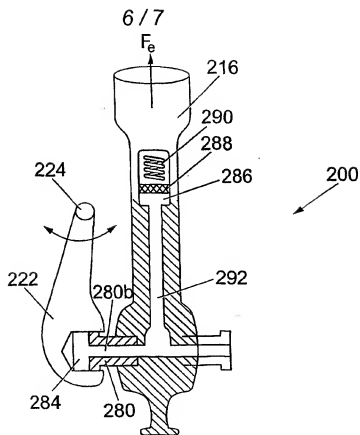


Fig. 7a

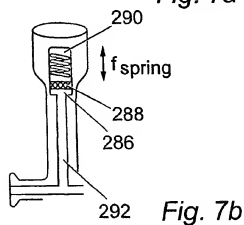


Fig. 7b

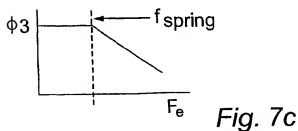
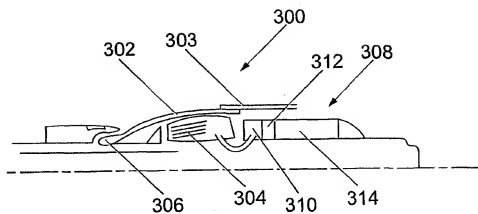
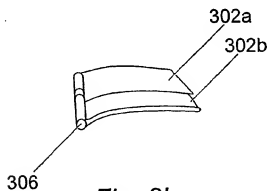


Fig. 7c

SUBSTITUTE SHEET (RULE 26)

7/7

*Fig. 8a**Fig. 8b*

SUBSTITUTE SHEET (RULE 26)



## INTERNATIONAL SEARCH REPORT

PCT/GB02/00356

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E21B43/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 785 193 A (KINLEY M ET AL) 15 January 1974 (1974-01-15)  column 4, line 29 - line 42 column 5, line 21 - line 37 column 6, line 45 - column 7, line 42; figures 4-6	1-11, 13-20, 33, 34
Y	----	12, 35
Y	US 2 627 891 A (CLARK PAUL B) 10 February 1953 (1953-02-10) column 3, line 39 - line 57; figures 1, 4	12, 35
A	US 4 319 393 A (POGONOWSKI IVO C) 16 March 1982 (1982-03-16) figures  ----- -/--	1, 13, 21, 26



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" documents which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"Z" document member of the same patent family

Date of the actual completion of the international search

19 April 2002

Date of mailing of the international search report

02/05/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentkanal 2  
NL - 2280 HV Rijswijk  
Tel: (+31-70) 340-2000, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Giorgini, G

## INTERNATIONAL SEARCH REPORT

PCT/GB02/00356

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 595 439 A (THOME PAUL) 11 September 1987 (1987-09-11) page 5, line 30 -page 6, line 7; figures 6,7 -----	1-5,13
A	US 3 245 471 A (HOWARD GEORGE C) 12 April 1966 (1966-04-12) figures 1,2 -----	1,13
A	WO 00 37773 A (PETROLINE WELLSYSTEMS LTD ;ASTEC DEV LTD (GB)) 29 June 2000 (2000-06-29) figures -----	1,13

## INTERNATIONAL SEARCH REPORT

PCT/GB02/00356

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3785193	A	15-01-1974	NONE	
US 2627891	A	10-02-1953	NONE	
US 4319393	A	16-03-1982	US 4220034 A US 4309891 A	02-09-1980 12-01-1982
FR 2595439	A	11-09-1987	FR 2595439 A1	11-09-1987
US 3245471	A	12-04-1966	NONE	
WO 0037773	A	29-06-2000	AU 1867900 A AU 1868700 A AU 1868800 A AU 1868900 A AU 1876600 A AU 1876800 A EP 1147287 A2 EP 1141517 A1 EP 1141515 A1 EP 1144802 A2 EP 1151180 A1 EP 1141518 A1 WO 0037766 A2 WO 0037771 A1 WO 0037768 A1 WO 0037767 A2 WO 0037772 A1 WO 0037773 A1 GB 2345308 A GB 2346632 A GB 2346400 A GB 2346909 A GB 2347445 A NO 20012596 A NO 20012597 A NO 20012598 A NO 20012599 A NO 20012600 A NO 20012865 A	12-07-2000 12-07-2000 12-07-2000 12-07-2000 12-07-2000 12-07-2000 24-10-2001 10-10-2001 10-10-2001 17-10-2001 07-11-2001 10-10-2001 29-06-2000 29-06-2000 29-06-2000 29-06-2000 29-06-2000 05-07-2000 16-08-2000 09-08-2000 23-08-2000 06-09-2000 27-07-2001 27-07-2001 30-07-2001 30-07-2001 30-07-2001 07-08-2001